In the Specification

Kindly amend paragraph 1 on page 1 as follows:

Technical Field

~~The present invention~~ This disclosure relates to machine structural steel products. In ~~more~~ particular, the ~~present invention~~ disclosure relates to a machine structural steel product having superior formability of rotary-forming, quenching-crack resistance, and torsional properties. A steel product is provided which is a machine structural steel product manufactured using an electric furnace instead of a blast furnace and which retains various properties even when a tramp element such as Cu or Ni is incorporated.

Kindly amend paragraph 2 on page 1 as follows:

Background ~~Art~~

Machine structural members such as drive shafts for automobile use and constant velocity joints have been requested to have a torsional strength at a required level. In order to ensure the torsional strength, heretofore, a hot-rolled steel bar has been generally processed by the steps of hot-forging, normalizing whenever necessary, cutting, cold-forging, and the like so as to have a predetermined shape, followed by induction hardening and tempering.

Kindly amend paragraph 2 on page 2 as follows:

For improving the torsional strength, it has been considered that quenched hardness and hardness penetration depth are increased by induction hardening. However, in order to increase the quenched hardness and the hardness penetration depth, either the change in high-frequency hardening conditions or the increase of the amount of alloy elements in a steel product must be carried out. In both cases described above, the manufacturing cost is inevitably increased. In order to simultaneously satisfy the torsional strength, machinability, and quenching-crack resistance of automobile

components, for example, as disclosed in ~~Patent Document 1~~ Japanese Patent No. 3288563 a technique specifying the amount of alloy elements has been proposed.

Kindly amend paragraph 1 on page 3 as follows:

Accordingly, ~~in order~~ to solve the problems described above, ~~the inventors of the present invention~~ we proposed a machine structural steel product having superior machinability, quenching-crack resistance, and torsional properties as disclosed, for example, in ~~Patent Document 2~~ Japanese Patent No. 3288563 in which the steel texture is controlled at the same time when the components of the steel product are appropriately adjusted.

~~Patent Document 1: Japanese Unexamined Patent Application Publication No. 4-218641 (Claims)~~

~~Patent Document 2: Japanese Patent No. 3288563 (Claims)~~

Kindly amend paragraph 2 on page 3 as follows:

However, it was found that when the machine structural steel product disclosed in ~~Patent Document 2~~ Japanese Patent No. 3288563 is manufactured using an electric furnace, desired properties cannot be obtained, and in particular, degradation in formability of rotary-forming is significant. Compared to a steel product manufactured using a blast furnace, a tramp element such as Cu or Ni is inevitably incorporated into the steel product manufactured using an electric furnace. It is believed that the tramp elements deteriorate the formability of rotary-forming.

Kindly amend paragraph 1 on page 4 as follows:

~~A primary object of the present invention is to solve the problems described above. That is, an object of the present invention is~~ It could therefore be advantageous to provide a machine structural steel product which has superior quenching-crack resistance and torsional properties and which effectively prevents the degradation in formability of

rotary-forming even when manufactured using an electric furnace instead of a blast furnace. In addition, a drive shaft formed from this steel product ~~is also proposed~~ could be advantageous.

Kindly amend paragraph 2 on page 4 (bridging page 5) as follows:

~~Disclosure of Invention~~ Summary

~~Through long and intensive research carried out by the inventors of the present invention in order to achieve the above objects, the following findings were obtained.~~ We found:

(1) ~~In order to~~ To suppress the adverse influences of tramp elements, it is effective to increase the amount of Cr;

(2) however, the increase of the amount of Cr causes the degradation in formability of rotary-forming, and also causes the degradation in torsional properties and machinability;

(3) the degradation in torsional properties and machinability concomitant with the increase of the amount of Cr can be solved by increase of the amount of Si and, in addition, by decrease of the amount of Mn; and

(4) the degradation in formability of rotary-forming can be overcome when an LD value, which is an index of the texture and the hardness through the hardenability, is controlled in a predetermined range.

Kindly amend paragraph 1 on page 5 as follows:

~~The present invention was made on the above findings, and the particular aspects of the present invention are as follows.~~ We therefore provide:

1. A machine structural steel product provided with superior formability of rotary-forming, quenching-crack resistance, and torsional properties, which comprises: on a mass percent basis,

C: 0.35% to 0.50%;

Si: 0.15% or less;

Mn: 0.20% to 1.1%;

P: 0.02% or less;

S: 0.005% to 0.035%;

Cr: more than 0.1% to 0.2%;

Mo: 0.05% to 0.5%;

Ti: 0.01% to 0.05%;

Al: 0.01% to 0.05%;

N: 0.01% or less;

B: 0.0005% to 0.0050%;

Cu: 0.06% to 0.25%; and

Ni: 0.05% to 0.2%,

wherein an LD value represented by the following equation (1) of 120 or less is satisfied, and the balance of the composition includes Fe and inevitable impurities.

Note

$$LD=0.569\times\{7.98\times(C)\ [[\}]]^{1/2}\times(1+4.1Mn)\cdot(1+2.83P)\cdot(1-0.62S)$$

$$LD=0.569\times\{7.98\times(C)\}^{1/2}\times(1+4.1Mn)\cdot(1+2.83P)\cdot(1-0.62S)\cdot(1+0.64Si)\cdot(1+2.33Cr)\cdot(1+0.52Ni)\cdot(1+3.14Mo)\cdot(1+0.27Cu)\cdot(1+1.5(0.9-C))\}+52.6 \quad \cdots (1)$$

In the above equation, C, Mn, P, S, Si, Cr, Ni, Mo, and Cu in the equation each indicate the content (mass percent) of the respective elements.

Kindly amend paragraph 2 on page 7 as follows:

~~Best Mode for Carrying Out the Invention~~ Detailed Description

~~Hereinafter, the present invention will be described in detail~~. The reasons the

composition of a steel product ~~of the present invention~~ is specified in the above range will be described. ~~In the present invention,~~ "%" used for components indicates "mass percent", unless otherwise stated.

Kindly amend paragraph 1 on page 9 as follows:

Cr: more than 0.1%, 0.2% or less

Cr is a particularly important element ~~in the present invention~~, and when Cr is contained, the adverse influence of tramp elements such as Cu and Ni can be advantageously removed, the adverse influence being degradation in formability of rotary-forming, torsion properties, machinability, and the like. However, when the content of Cr is 0.1% or less, the effect of Cr component is not sufficient. On the other hand, when the content is more than 0.2%, since the formability of rotary-forming, machinability, and torsional strength are degraded, the content of Cr is set to more than 0.1% to 0.2%.

Kindly amend paragraph 1 on page 12 as follows:

The primary components are described above, and ~~according to the present invention~~, in addition to those components, the following elements may also be optionally used.

V: 0.01% or more, 0.30% or less, and Nb: 0.005% or more, 0.050% or less

Kindly amend paragraph 3 on page 12 (bridging page 13) as follows:

Although the appropriate ranges of the components are described above, ~~according to the present invention~~, it is not enough that the individual components simply satisfy the above ranges, and the individual components must be controlled so that the LD value represented by the following equation (1) is 120 or less.

~~Note~~

$$LD=0.569\times\{7.98\times(C)\,[[\}]]^{1/2}\times(1+4.1Mn)\cdot(1+2.83P)\cdot(1-0.62S)\cdot(1+0.64Si)\cdot(1+2.33Cr)\cdot(1+0.52Ni)\cdot(1+3.14Mo)\cdot(1+0.27Cu)\cdot(1+1.5(0.9-C))\}+52.6 \quad \cdots (1)$$

Kindly amend paragraph 3 on page 13 as follows:

Fig. 1 shows the results of measurement of the influence of the LD value on the formability of rotary-forming of high Cr steel and high Si steel. In addition, in the figure described above, the results of measurement of low Cr and low Si steel disclosed in ~~Patent Document 2~~ Japanese Patent No. 3288563 described above are also shown for comparison.

Kindly amend paragraph 5 on page 13 as follows:

As shown in the figure, in both cases, when the LD value is more than 120, the die life is rapidly decreased; however, when the LD value is 120 or less, the die life, that is, the formability of rotary-forming, of the high Cr and high Si steel ~~of the present invention~~ is much superior.

Kindly amend paragraph 6 on page 13(bridging page 14) as follows:

Accordingly, ~~in the present invention~~, the components are controlled to obtain an LD value of 120 or less.

Kindly amend paragraph 1 on page 14 as follows:

~~In the present invention~~, ~~the~~ The steel texture is not particularly specified; however, a texture composed of ferrite as a primary component and approximately 5 to 30% of a bainite phase on an area percent basis is preferably used.

Kindly amend paragraph 3 on page 14 as follows:

Next, preferable manufacturing conditions ~~according to the present invention~~ will be described.

Kindly amend paragraph 4 on page 14 (bridging page 15) as follows:

A steel melting method for the steel product ~~of the present invention~~ may be performed by a known method and is not particularly limited. The machine structural steel ~~of the present invention~~ has superior formability of rotary-forming even when Cu or Ni is incorporated, which is difficult to be removed in steel melting performed by using an electric furnace, and hence the steel melting is preferably performed using an electric furnace. Vacuum degassing such as RH degassing, refining using ladles, and the like may be additionally performed. Molten steel is solidified by a continuous casting method or an ingot-making method and is then formed into materials having predetermined shapes through hot rolling or hot/warm forging. After being processed by intermediate heat treatment, whenever necessary, such as normalizing, spheroidized annealing, or softening annealing, the materials thus obtained are finished into a desired shape by cold working such as cutting, forging, or form rolling.

Kindly amend paragraph 1 on page 15 as follows:

~~In the present invention, the~~ The product having a predetermined shape is formed by hot rolling or hot forging, or is then further processed by normalizing. Cooling after the formation of austenite by this hot rolling or hot forging followed by normalizing or the like is preferably performed at a rate of approximately 0.2 to 2.0°C/sec ~~in order~~ to produce an appropriate amount of bainite. In particular, for a steel bar having a large diameter, accelerated cooling in which cooling is controlled is preferably performed.

Kindly amend paragraph 2 on page 18 as follows:

As can be apparently seen from Table 2, the steel products obtained ~~according to the present invention~~ have superior formability of rotary-forming, torsional properties, quenching-crack resistance, and machinability.

Kindly amend paragraph 3 on page 18 as follows:

The static strength and the fatigue strength of a drive shaft, which was formed from the steel product ~~of the present invention~~ provided with a hardened layer by induction hardening and tempering, will be described with reference to Figs. 2 and 3, respectively. The drive shaft of the example ~~according to the present invention~~ was formed from a steel product of No. 2 shown in Table 1. The drive shaft of the comparative example was formed from a steel product of No. 18 shown in Table 1. Fig. 2 is a graph showing the results of measurement of the static strength of the drive shafts by a static strength test. The static strength test (static strength test) is to evaluate the static strength by measuring the maximum torque obtained when the drive shaft is broken. The number of the drive shafts used for the test was one for the comparative example and two for the examples. The results of the comparative example, example 1, and example 2 are shown in Fig. 2. The maximum torque obtained when the drive shaft of the comparative example was broken is set to be 1, and the maximum torque obtained when the drive shaft of the example was broken was represented by the ratio thereto. It was understood that the static strength of the drive shaft of the example was improved by approximately 1.17 times that of the drive shaft of the comparative example.

Kindly amend paragraph 1 on page 20

Industrial Applicability

~~According to the present invention, adverse~~ Adverse influences of tramp element can be removed even from a machine structural steel product manufactured by using an electric furnace, the tramp elements being inevitably incorporated in the steel product. A steel product can be obtained having superior formability of rotary-forming, torsional properties, quenching-crack resistance, and hardenability. In particular, when the steel product ~~according to the present invention~~ is used for forming power transmission devices, such as automobile drive shafts and velocity constant joints, in addition to superior machinability, significant advantage, that is, weight reduction, can be obtained due to the high strength.